Power Systems

- Thermal Power
- Hydraulic Power
- New Energy
- Electric Power Distribution

Thermal Power Plants with Zero Emissions Made Possible by Coal Gasification Combined Cycle

The world has very large reserves of coal and while attention has been directed toward its use as an alternative energy source to oil, there is a need to reduce the large CO_2 emissions associated with coal-fired thermal power generation significantly. Improving the efficiency of coal-fired thermal power generation is also the key to reducing CO_2 emissions and Hitachi is working on achieving this using proprietary coal gasification technology that it has been researching, developing, and demonstrating for more than 30 years. Hitachi also has an environmental strategy based on a time-frame of several decades and is working on environmental efficiency in various different products.

EAGLE pilot plant

Culmination of Technology Developed over More than 30 Years

Following the oil shock of the early 1970s, Japan adopted a new energy policy of avoiding reliance on oil. Prior to that time, Japan had been undergoing a shift toward greater use of oil as indicated by the fact that 99% of thermal power generation at the time was fueled by oil, but this was also the time when our country started development of new non-oil energy sources such as solar thermal power generation. One such technology was the use of coal gasification to burn coal in a gas turbine. Hitachi developed and patented technology for reducing CO_2 (carbon dioxide) emissions using a proprietary single-chamber, two-stage swirling-flow gasifier. Since then, Hitachi has spent more than 30 years establishing the technology of coal gasification combined cycle power generation including operating trial plants.

Through the EAGLE (coal energy application for gas, liquid and electricity) gasifier which has been in design and development since the mid-1990s, Hitachi has participated in the Multi-purpose Coal Gas Production Technology Development (EAGLE) which is being conducted jointly with the New Energy and Industrial Technology Development Organization (NEDO) and Electric Power Development Co., Ltd. We are working on establishing technologies including gasification, gas purification, and operation technologies for power generation systems, and have supplied a plant to Electric Power Development Co., Ltd. and provided it with support for pilot operation.

CO_2 Emission Reduction and Capture

An IGCC (integrated coal gasification combined cycle) system converts coal into a combustible gas (carbon monoxide and hydrogen) in a gasifier operating at high temperature and pressure which is used to fuel a gas turbine and generate electric power. The heat from the gas turbine exhaust gas and the reaction heat of the gasifier are recovered to produce steam which is supplied to a steam turbine and used for co-generation. System verification testing of IGCC was undertaken at EAGLE which demonstrated that highly efficient coal gasification can be achieved with low oxygen by using single-chamber, two-stage swirling-flow gasification. Test operation completed in March 2007. The gasifier was then upgraded to expand the range of coals able to be used and further trials conducted up until March 2010 under the title "EAGLE-step2." In EAGLE-step2, part of the existing plant was separated and, in a world first, used to demonstrate the capture of CO_2 from coal gasification gas with a CO_2 capture ratio of better than 90% and CO_2 purity above 99%. With the aim of improving reliability further, demonstrations are still continuing at the pilot plant to investigate various technical issues such as the control of the gasifier which reaches temperatures of 1,500℃ or higher.

Work Aimed at Achieving Zero Emissions

In recent years, the development of energy sources that do not rely on oil has once again become an issue. In other words, the reality of Japan's energy situation has not changed at all. Against this background, attention is once again being directed at coal as a way of providing a reliable supply of energy, it being a resource with vast reserves. Coal currently makes up about 30% of the fuel used for thermal power generation compared to only a few percent for oil and there are high expectations for the IGCC technology being promoted by Hitachi as a way of utilizing coal while taking account of the environmental problem of global warming. Currently, only five IGCC plants are in operation world-wide and all are at the demonstration stage.

An extensive market is opening up for IGCC including in emerging economies for which the provision of energy infrastructure will gain momentum in the future. IGCC with its high efficiency and ability to deal with CO_2 has the potential to become a zero-emission system that does not emit any CO_2 and Hitachi's intention is to pursue harmony between energy technology and the global environment from a long-term perspective.

Eiji Kida (left), General Manager, Energy Systems and Board Director, Babcock-Hitachi K. K.; Nobuo Nagasaki (right), Department Manager, Thermal Power Development Center, Thermal Power Systems Development & Management Division, Thermal Power Systems Division, Power Systems Company, Hitachi, Ltd.

Collaboration with Saskatchewan Government on Energy and Environment Technology Development

Hitachi has supplied a large quantity of thermal, hydro, wind, and other power generation equipment to the Saskatchewan Power Corporation which supplies power to the state of Saskatchewan in Canada in a variety of forms. Hitachi also has close links with local industry through Hitachi Canadian Industries Ltd. which was established in 1988 to produce power generation equipment in the City of Saskatoon, Saskatchewan.

In February 2010, Hitachi's Power Systems Company signed a new agreement with Saskatchewan Power Corporation to undertake joint development of CCS (carbon capture and storage) and other low-carbon energy technologies to help create a low-carbon society.

In May of the same year, the Saskatchewan government and Hitachi announced they had agreed on a joint declaration for collaboration on energy and environment technology development which expresses their strategy for broad-based contribution to society.

Announcement by Saskatchewan Government and Hitachi of collaboration on energy and environment technology development (Saskatchewan Premier Brad Wall and Hitachi, Ltd. Representative Executive Officer and President Hiroaki Nakanishi shake hands after announcing the joint declaration.)

For the future, further collaboration on technology development with regional communities is anticipated in areas such as the trialing of CCS technologies for reducing the CO_2 (carbon dioxide) emissions of coal-fired power generation and the operation of power grids that incorporate renewable energy. In its role as one of Hitachi's development centers in North America, this project is also seeking to contribute internationally in the fields of energy and the environment.

Commencement of Commercial Operation at NBCC1 Plant of Thailand Power Company EGAT

EGAT's NBCC1 power plant in Thailand

The North Bangkok Combined Cycle Power Plant Block 1 (NBCC1, total capacity: 704 MW) of the Electricity Generating Authority of Thailand (EGAT) commenced commercial operation during November 2010. To deliver both a reliable electricity supply and protection of the environment, EGAT has adopted combined cycle plants fueled by natural gas for the bulk of its planned new power generation capacity and has had multiple projects under construction in parallel. NBCC1 has attracted attention as a symbolic new power plant constructed in the same complex as EGAT's headquarters. The contract was undertaken by a consortium made up of Hitachi, Ltd., Sumitomo Corporation, and the Thai construction company Italian-Thai Development PCL, each of which contributed their particular skills to the project.

Hitachi's roles in the project were engineering, procurement, commissioning, and technical advice for construction. The core components of the highly efficient combined cycle plant, namely the steam turbine along with the generator, transformers, and control systems were supplied by Hitachi while the gas turbines and heat recovery steam generators were procured from major global suppliers. Hitachi also acted as the technical leader and undertook overall technical coordination within the consortium. It is anticipated that NBCC1 will play an important role as a core power plant providing reliable supply of power to Bangkok and surrounding areas.

473-MVA Turbine Generators Supplied to GECOL Al Khalij Power Plant in Libya

473-MVA turbine generators for the Al Khalij Power Plant of the General Electricity Company of Libya (GECOL) have completed construction at the factory and been shipped. The units are supplied through a contract with Hyundai Engineering & Construction Co., Ltd. of South Korea.

The turbine generators are the latest Hitachi model featuring indirect hydrogen cooling of the stator. This uses hydrogen gas to cool the stator coil indirectly via the main insulation, providing much better efficiency and allowing a simpler design to be used for the auxiliary generator systems compared to direct water cooling of the stator which was used on previous models of similar capacity.

In addition to detailed study carried out from the design stage, the manufacture of these turbine generators included conducting operational testing in the factory to confirm that the units complied with the required specifications. This verified their high performance which includes better than 99% efficiency.

473-MVA turbine generator for GECOL's Al Khalij Power Plant in Libya

The turbine generators are scheduled to be brought on line progressively following on-site installation and commissioning.

[Main specifications]
Capacity: 473 MVA
Power factor: 0.8
Voltage: 19 kV
Current: 14,373 A
Speed: 3,000 min^{-1}

Commencement of Commercial Operation at Stage 3, Futtsu Thermal Power Station Group 4 of The Tokyo Electric Power Co., Inc.

Stage 3 at Futtsu Thermal Power Station Group 4 of The Tokyo Electric Power Co., Inc.

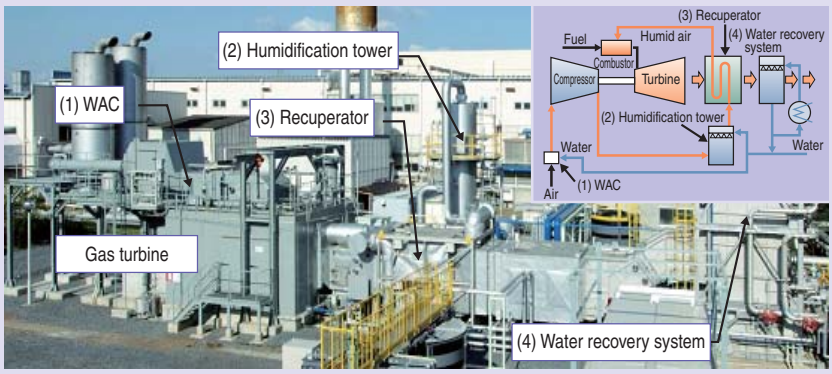
The Tokyo Electric Power Co., Inc. started commercial operation of Stage 3 at its Futtsu Thermal Power Station Group 4 in October 2010. The unit's equipment is intended to take up the role of providing future urban-based LNG (liquefied natural gas) thermal power generation and, in particular, it is designed for environmental sustainability and to achieve high thermal efficiency in order to conserve energy.

The project was a difficult one to coordinate as the powertrain, control system, and other equipment used in the unit were supplied by General Electric Company (GE) and others while Hitachi's role included the supply of the waste heat recovery boiler, condenser, and various auxiliary systems as well as the installation of its own and all other companies' equipment, unit testing, and trial operation.

The Futtsu Thermal Power Station Group 4 has been designed as a combined-cycle generation plant using 1,500℃-class gas turbines. Its GE MS9001H gas turbines which use steam to cool their high-temperature parts achieve a stage output of 507 MW (at an ambient temperature of 10℃) and thermal efficiency of about 59%.

For the future, Hitachi intends to utilize its total engineering capabilities to focus its efforts on overall coordination of new projects in Japan and other parts of the world including the construction of highly efficient thermal power plants that take account of environmental considerations.

Completion of Testing of New AHAT Gas Turbine Generator System



WAC: water atomization cooling

3-MW-class AHAT pilot plant (Hitachinaka City, Ibaraki Prefecture)

Hitachi has been working on AHAT system testing and technology development with Sumitomo Precision Products Co., Ltd. and the Central Research Institute of Electric Power Industry since the 2004 financial year as part of a national project sponsored by the Ministry of Economy, Trade and Industry. System testing was conducted at a 3-MW AHAT pilot plant in March 2007 and in February 2010 it was confirmed that NO*x* (nitrogen oxides) emissions were 10 ppm or less and that the startup time was less than one-third that of GTCC generation. This work is highly regarded by industry bodies globally and was awarded a prize at the American Society of Mechanical Engineers' annual awards for best technical papers in June 2010. Currently, further technical development work is being undertaken on a 40-MW-class test unit which is scheduled for completion in 2012.

AHAT (advanced humid air turbine) cycle generation is a way of generating electric power from a gas turbine by burning the fuel in humid air. Whereas GTCC (gas turbine combined cycle) generation generates power both from a gas turbine and from a steam turbine that utilizes its exhaust heat, AHAT generation uses a single gas turbine to generate power from both combustion gas and steam thereby achieving lower cost and high efficiency.

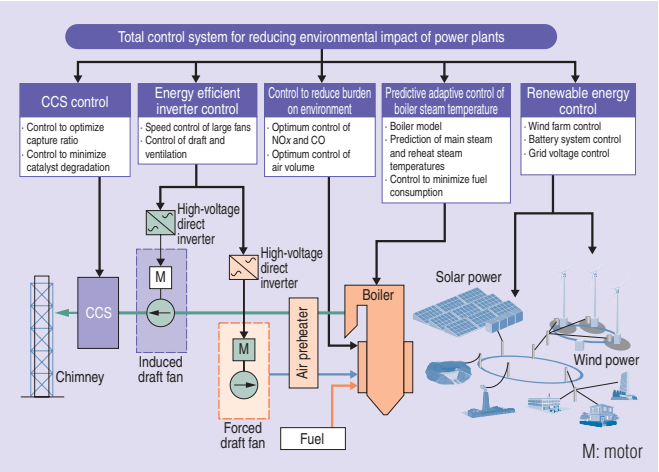
For the future, the aim is to commercialize mid-range systems (100-MW class) for use at new power plants and as replacements at aging thermal power plants, and also other applications such as its use as a power source that can help stabilize the grid in the presence of renewable energy.

Total Control System for Reducing Environmental Impact of Power Plants

Various measures are being adopted to reduce the burden that power plants place on the environment and one technology that Hitachi has already commercialized is the use of energy-efficient inverter systems based on high-voltage direct inverters which reduce CO_2 (carbon dioxide) emissions through higher efficiency. Another plan in the field of boiler control is the addition of a new function for predictive adaptive control of boiler steam temperature aimed at saving energy by minimizing fuel consumption as well as improving the load response performance. It is also anticipated that control systems that reduce the burden on the environment using self-tuning algorithms based on reinforcement learning (currently being in demonstration process) will perform optimum control of emissions of compounds such as CO (carbon monoxide) and NO*x* (nitrogen oxides) and contribute to improvements such as better combustion efficiency and lower power consumption by ventilation fans.

Control technology is also being developed for technologies like CCS (carbon capture and storage) that have attracted attention in recent years as a way of mitigating global warming along with renewable energy sources such as wind and solar power. In the case of CCS control, control techniques are being developed that can minimize the loss in plant efficiency while maintaining compliance with environmental regulations. In the case of renewable energy sources such as wind and solar power, attention is being directed toward the development of control techniques that incorporate battery systems to provide a stable connection to the grid.

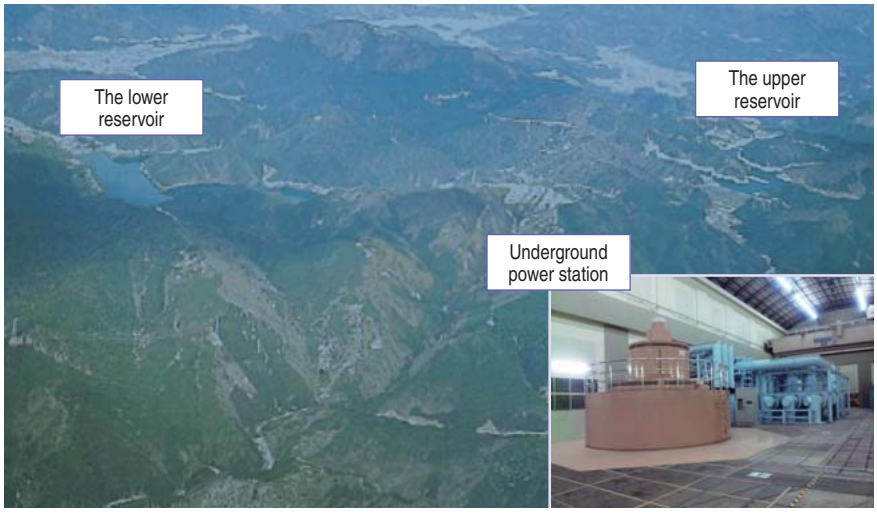
In the near future, Hitachi plans to combine various control technologies for improving energy efficiency and reducing the burden on the environment that have been designed to suit different generating plant outputs and operating practices to produce a total control system for reducing the environmental impact of power plants.



Total control system for reducing environmental impact of power plants

This system takes maximum advantage of the various control technologies it incorporates to minimize CO_2 emissions, conserve energy, and operate with high efficiency. It is believed that the system will enhance the flexibility of grid connectivity through better load response performance (advances in economic load dispatch control) with significant benefits for grid stability as use of renewable energy increases.

Adjustable-speed Operation of 320-MW Motor-generator at Okutataragi Power Plant of The Kansai Electric Power Co., Inc.



Okutataragi Power Plant of The Kansai Electric Power Co., Inc.

The use of adjustable-speed pumped storage systems to provide an energy storage mechanism able to adjust the balance of power supply and demand was commercialized in the late 1990s and has since made a major contribution to the economic operation of the electricity system and to reducing emissions of greenhouse gases. Meanwhile, the promotion of energy efficiency in recent years and growing use of wind, solar, and other renewable energy sources have created a need for greater power supply and demand balancing capacity. Although adjustable-speed pumped storage systems are ideal for this purpose, the need for dams and other major construction work means they face a problem of long construction lead times.

Taking advantage of the replacement of aging equipment at its Okutataragi Power Plant which had been in use for more than 30 years, The Kansai Electric Power Co., Inc. decided to convert its existing constant-speed motor-generators to adjustable-speed operation with the aim of improving the plant's capacity for balancing power supply and demand. For environmental reasons, much of the equipment at the Okutataragi Power Plant is housed in an underground facility and this created numerous challenges for the adjustable-speed conversion project including the need to make effective use of the available space. Following extensive preliminary investigations, however, these problems were overcome and construction is now underway. The first unit is scheduled to enter service in 2013 followed by a second unit in 2014.

81.1-MW Francis Turbine Runner Upgrade for Tangga Power Plant in Indonesia

The Tangga Power Plant draws its water from Lake Toba in the central part of the Indonesian island of Sumatra and was constructed with the help of yen loans from Japan under the Asahan Plan with the primary aim of supplying the power for an aluminum smelter. Hitachi supplied four turbines which commenced operation in 1983. Following the submission of a proposal to improve turbine efficiency to the customer and the conducting of an on-site study preliminary to an improvement project, Hitachi received an order in 2006 to upgrade the runners (main turbine wheels) for three of the turbines, excluding Unit 1. After supplying the equipment, Hitachi completed the overhauls of Units 2 and 3 in September 2009 and July 2010 respectively, while the Unit 4 overhaul is scheduled for 2012.

The overhaul improved the turbine efficiency by 5 to 6% by upgrading to optimally designed runners and guide vanes, improving the stay vane shape, and fitting flow guides to the flow entry region going from the casing to the stay vanes. Not only has the upgrade helped boost the operating efficiency of the aluminum smelter, it is also anticipated that it will make an increasing contribution to the economic growth of Indonesia, an emerging nation, with ownership of the power plant to be transferred in 2013 to the Indonesian government which aims to undertake integrated production of aluminum.


81.1-MW Francis turbine runner for Tangga Power Plant in Indonesia

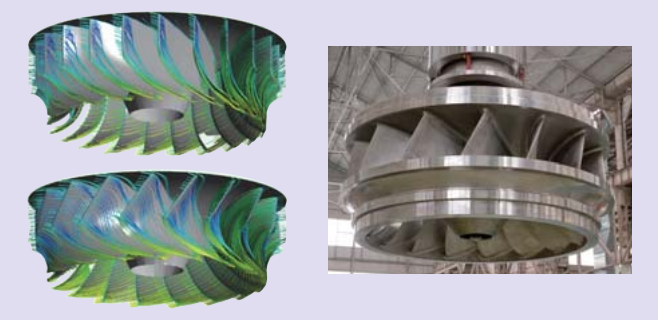
Turbine specifications (after overhaul)
Head: 226.8 m (rated)
Turbine output: 81.1 MW (max.)
Turbine speed: 333 min^{-1} (rated)

Runner Replacement and S&B Upgrade of Hydro Turbines Using CFD-based Turbine Design Techniques

To ensure the effective use of hydro generation resources, Hitachi uses the latest turbine design techniques to upgrade existing power plants, including both the replacement of individual components and full S&B (scrap and build) turbine replacements. In particular, the output range of the turbine can be extended and the water in the reservoir used more efficiently if the turbine is able to operate at 30% or less of its rated flow rate. In addition to improvements to the turbine efficiency over its operating range, this also requires a reduction in the flow-induced vibrations in the turbine which is a factor in whether or not the turbine is able to operate. To solve this problem, Hitachi adopted a runner with forward-lean blades that were optimized using CFD (computational fluid dynamics) flow analysis.

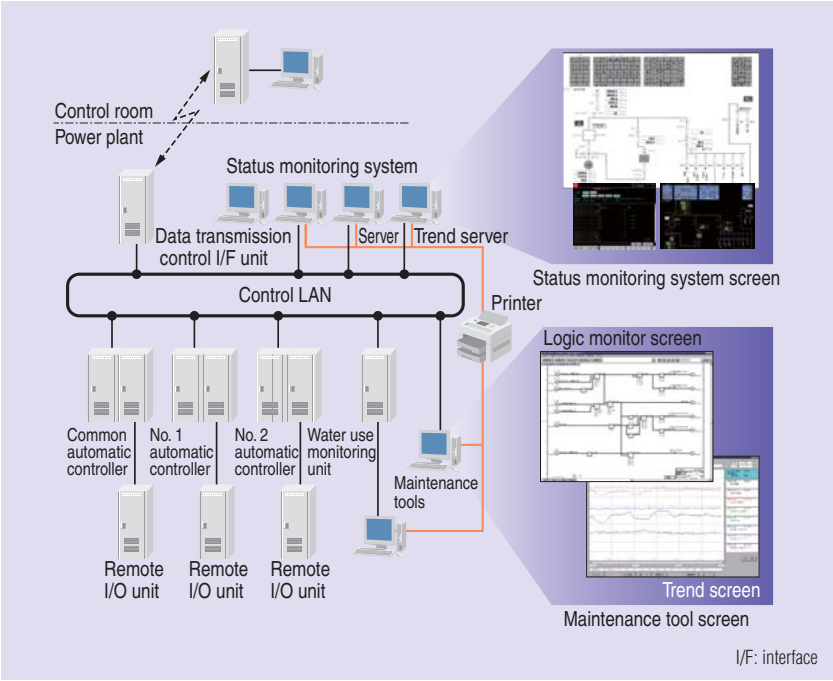
In order to upgrade the 125-MW Francis turbine at Arimine Power Station Unit 2 of Hokuriku Electric Power Company which commenced operation in 1981 to allow operation at below 30% flow rate by replacing the runner only, Hitachi used CFD and model testing to optimize the design of a runner with forward-lean blades. The welded parts of the new runner are currently being fabricated with a target delivery date of October 2011 and operation is scheduled to restart in December of the same year after the upgrade work is completed.

Hitachi also upgraded the 11.1-MW Francis turbine at Oike No. 2 Power Plant of Tohoku Electric Power Co., Inc. which has been in use for more than 50 years having commenced operation in 1956. The upgrade involved replacing the entire turbine except for the draft tube. Oike No. 2 is a run-of-the-river power plant and the project involved installing a runner with forward-lean blades with turbine characteristics designed to maximize the total annual power generation together with the use of CFD to optimize other features of the flow path. For environmental reasons, the turbine uses water-lubricated bearings instead of lubricating oil.



CFD analysis of turbine runner for Arimine Power Station Unit 2 of Hokuriku Electric Power Company (left) and runner with forward-lean blades for Oike No. 2 Power Plant of Tohoku Electric Power Co., Inc. (right)

Upgrade of Automatic Controller to Use HIACS Monitoring and Control System



System configuration for Numazawa No. 2 Power Station of Tohoku Electric Power Co., Inc.

Hitachi has completed manufacture of the No. 2 automatic controller, governor controller, and excitation controller for the upgrades to the No. 1 and No. 2 control units at the Matanogawa Power Station of The Chugoku Electric Power Co., Inc. and supplied these to the site. The automatic controller is to be upgraded from a first-generation digital controller supplied in 1986 to the HIACS (Hitachi integrated autonomous control system) monitoring and control system. Trial operation commenced on unit 2 in February 2011 and commercial operation began in June. The No. 1 control unit was delivered in April 2011 and is currently undergoing trial operation prior to entering commercial operation in September.

Hitachi is also currently undertaking design and manufacturing work for an upgrade from a relay-based system to HIACS for the No. 1 and No. 2 automatic controllers at the Numazawa No. 2 Power Station of Tohoku Electric Power Co., Inc.

The key features of the HIACS-based units are as follows.

(1) Remote I/O (input/output) units are used to minimize external cabling.

(2) Maintenance tools including CAD (computer-aided design) functions are provided to simplify program design, testing, and maintenance.

(3) A control LAN (local area network) is used for data transfer.

Large-scale Solar Power Plants

Use of solar, wind, and other forms of renewable energy that do not consume fossil fuel or emit carbon dioxide has grown all over the world in recent times because of the desire to reduce carbon dioxide emissions. In the field of solar power generation, Japanese electric power companies are planning to construct more than 140 MW of solar power capacity at approximately 30 locations around Japan between now and 2020. Private companies and local governments are also proceeding with similar plans to develop plants in many areas.

On the other hand, there are a number of technical and economic issues that accompany greater use of solar power.

Firstly, since solar power plants generate electric power from solar energy, the amount of power generated depends entirely on the quantity of solar radiation and this means that the power output fluctuates depending on the weather. For this reason, measures to minimize the effect of this fluctuation on the power grid will be needed.

Hitachi has developed and utilized grid interconnection technologies such as a voltage stabilizing function and fault ride through function. Hitachi has also commercialized core products for large-scale solar power plants including very efficient high-capacity power conditioners, monitoring and control systems, transformers, and switchgear. Based on this technology and experience, Hitachi can build highly efficient and reliable power generation systems.

A second issue is that reaching grid parity (bringing the cost of solar power down to the level of grid power) will be a key factor in achieving wider adoption of large-scale solar power plants. To achieve this, it will be necessary to minimize the cost of construction and grid connection and maximize the amount of power generated and the depreciation period.

Regarding grid connectivity, Hitachi intends to continue applying the grid interconnection technologies described above while developing and introducing more reliable and efficient equipment to maximize power generation capability. To reduce construction costs, Hitachi will also adopt sophisticated and efficient designs including using optimized mounting structures for solar modules and determining the best layout for the PV (photovoltaic) modules in a solar power plant based on an analysis of the wind pressure to which they are subjected.

Hitachi has been accelerating its activities in the fields of renewable energy and smart grids since 2009 and also intends to expand into related areas to help achieve a low-carbon society.

Image photo of Japan's largest mega solar power plant located on Ohgishima Island (14 MW)

Completion of a New Converter for 1.5-MW Wind Power Generation Plant Using Doubly-fed Induction Machine

Completion of a new converter for 1.5-MW wind power generation plant using doubly-fed induction machine

Government-led installation of wind, solar, and other renewable energy capacity in China has been increasing recently with the aim of reducing CO_2 (carbon dioxide) emissions and this is driving rapid growth in demand for wind turbine generation equipment. Hitachi has been involved in the renewable energy market in China since 2006 including the completion of a new converter for 1.5-MW wind power generation plants using doubly-fed induction machines.

Converters installed in Shandong Province in 2008 are operating reliably and Hitachi has now developed a new smaller model with higher performance with the aim of increasing market share. Trial operation of the new converter at a site in the Inner Mongolia Autonomous Region has been completed in January 2010. The new model has the following features and Hitachi is currently in the process of supplying 400 units to the Chinese market.

(1) Support for industrial network standards (CANopen*1 and PROFIBUS*1)

(2) LVRT*2 (low voltage ride through) function

The LVRT function minimizes the ill effects of a grid fault on the wind generator by reducing the resulting fluctuation in generator torque.

Hitachi intends to take advantage of these features to expand its participation in the field of new energy.

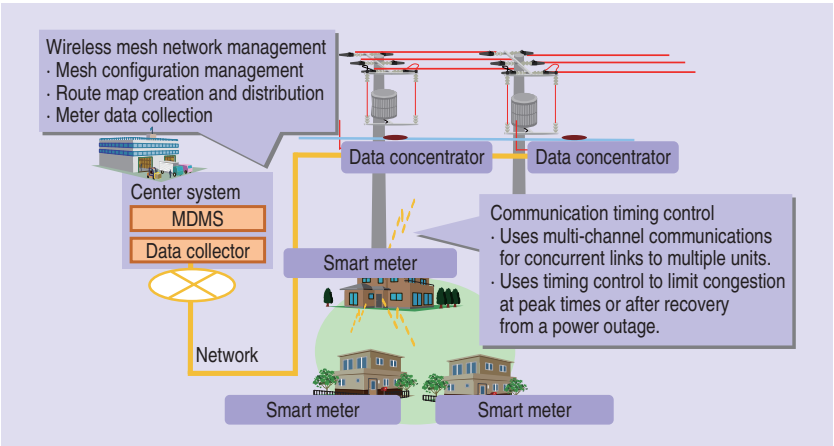
*1 See "Trademarks" on page 83.

*2 A function that prevents the generator from shutting down in the event of a short-duration grid fault

Advanced Metering Infrastructure

Work is in progress in Japan on testing and trialing the use of remote electricity meter reading based on the installation of smart meters incorporating communication functions. The aims include giving low-voltage consumers better information about their energy use, providing customers with new added-value services, and further improving business efficiency.

The introduction of smart meters with communication functions commenced in 2007 with a series of trials conducted by the regional power companies and Hitachi was responsible for the main AMI (advanced metering infrastructure) components including the supply of communication units incorporated in smart meters to provide wireless communications, the supply of wireless mesh network technology for the transmission of meter data, and the provision of an MDMS (meter data management system) for managing the large volumes of meter data.



AMI system block diagram

The wireless communication method used by AMI is subject to a limited transmission range (from tens to hundreds of meters) and this means that the communication unit in a smart meter installed at a customer home will not necessarily be able to communicate directly with data concentrator units that are installed on power poles or similar locations.

Hitachi supplied the overall mesh network technology including a multi-hop communication method that can communicate with a data concentrator via a number of intermediate meter units and techniques for preventing congestion of the available wireless communication bandwidth [which ranges from narrow (4,800 byte/s) to broad (several Mbyte/s)] including multi-channel operation and control of communication timing. The system is able to perform remote collection from many hundreds (typically about 500) of smart meters via a single data concentrator at 30-minute intervals.

In addition to utilizing trials to make further enhancements to the wireless mesh network, Hitachi intends to continue its participation in AMI system implementation in Japan and the world.